

Research Report 1471

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Army Maintenance Training and Evaluation Simulation System (AMTESS): Lessons Learned

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**John J. Kessler, Douglas H. Macpherson,
and Angelo Mirabella**



**Logistics Training Technologies Technical Area
Training Research Laboratory**



U. S. Army

Research Institute for the Behavioral and Social Sciences

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20. Abstract (Continued)

Specs that had proven to be problems in past acquisitions. It was further concluded that job aids should be developed to help the spec writer, since that job demands the skills of a technical writer, human factors specialist, and instructional designer, as well as those of an engineer.

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Army Maintenance Training and Evaluation Simulation System (AMTESS): Lessons Learned

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FOREWORD

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), in conjunction with PM-TRADE and Training and Doctrine Command (TRADOC), performs research and development that will lead to more cost-effective training devices. To this end, ARI joined with PM-TRADE and TRADOC in a Joint Working Group (JWG) called "AMTESS AS CBI." This report was initiated by JWG to capitalize on and climax 3 years of development and evaluation of AMTESS prototypes. It does so by extracting lessons learned about how to design and acquire maintenance training devices.

The report was requested during the October 1986 In Training Review (IPR) with PM-TRADE. The results were briefed to the Commanders of PM-TRADE and ARI as part of the April 1987 IPR. An outcome of that briefing was an agreement by the Commanders to use this report as a potential basis for developing decision aids for device specification writers.



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ACKNOWLEDGMENTS

A number of people contributed significantly to this report. We wish to thank Drs. Robert Swezey and Dennis Faust of Science Applications International Corporation (SAIC) for preparing major portions of the Device Acquisition Guidelines in Appendix A and for helping to refine those guidelines. Charles Bush and Doug Elam, also of SAIC, provided us with valuable information on how specifications for devices are developed, particularly under the new MANPRINT umbrella. They also reviewed the draft of this report and made many valuable comments and suggestions that we used to revise the document. Mr. Karl Driskell of PM-TRADE was instrumental in initiating this project and providing much valuable background information on how device concepts are formulated and specified. Dr. Robert Seidel provided very strong support and overall direction to this effort.

ARMY MAINTENANCE TRAINING AND EVALUATION SIMULATION SYSTEM (AMTESS):
LESSONS LEARNED

EXECUTIVE SUMMARY

Requirement:

Using lessons learned from the AMTESS Program develop and test guidelines on how to acquire training devices.

Procedure:

The AMTESS program produced 11 reports. To meet the objectives stated above, these reports were systematically searched according to a conceptual strategy designed to yield documentation of the following:

1. AMTESS research results that suggest or indicate how future equipment might be designed more effectively.
2. References in the AMTESS reports to sources of published guidance on how to design training equipment.
3. AMTESS research that points to the need for additional research data on how to design training devices.
4. Suggestions on how to improve acquisition procedures and avoid pitfalls in equipment acquisition.

A categorization scheme that organizes the extracted documentation into six major divisions was developed. The scheme and its divisions were formatted to provide a guide--a list of "dos" and "don'ts" for future training device acquisition projects. To test the guide's usefulness it was tried out in a reverse engineering mode on the specifications for the Bradley Fighting Vehicle Maintenance Trainer (BFVMT). The guide was used to evaluate the quality of specifications for the hands-on and panel components of the trainer.

Findings:

Two kinds of recommendations emerged from the AMTESS experience. One is specific and quantitative: For example, "CRT screens should respond in .5 seconds to learner input." The other kind of recommendation is a general application of the guide to the Bradley Trainer Specifications, indicating that there are many fundamental problems with the way specs are now written, but also many opportunities for improvement, even with the current state of knowledge about device design and acquisition. The report details these problems, as well as specific suggestions for solving them.

Utilization of Findings:

The device acquisition guidelines (DAG) contained in this report can help Training and Doctrine Command (TRADOC) formulate device requirements and PM-TRADE prepare Request for Quotation (RFQ) specifications. The Device Acquisition Guideline (DAG) can point to categories of specification that need to be highlighted as well as provide some of the specifications.

ARMY MAINTENANCE TRAINING AND EVALUATION SIMULATION SYSTEM (AMTESS):
LESSONS LEARNED

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ARMY MAINTENANCE TRAINING AND EVALUATION SIMULATION SYSTEM (AMTESS):
LESSONS LEARNED

1.1 Overview

- a. This report summarizes the final effort in the AMTESS¹ Program. The report documents "Lessons Learned" about how to develop specifications for training devices. These lessons have been organized as a set of "Device Acquisition Guidelines". In Section 2 and 3 we describe how the guidelines were constructed and applied in a reverse engineering exercise to the specifications for the Bradley Maintenance Trainer.
- b. In Sections 3 and 4, we recommend how the current practices for specifying device characteristics might be revised to better account for training effectiveness and related human factors issues. In retrospect, the AMTESS program proved to be an invaluable opportunity to illustrate how device acquisition problems could be reduced through better specifications to device builders.

1.2 Background: AMTESS Program

- a. Excellent summaries of the AMTESS program and what inspired its birth are presented by Hofer (1981) and Dybas (1983). Additional details are provided by Evans and Mirabella (1982), and in the AMTESS evaluation reports (Appendix C). But, briefly the program goal was to acquire and test alternative generic, maintenance training prototypes and then use the results of the tests to produce a set of general specifications for acquiring such devices.
- b. Prototypes were built by Grumman and by Seville/Burtek. Each consisted of a microcomputer, one or more two-dimensional displays and a three-dimensional mock-up (e.g. full-scale diesel engine, starting system components, or high powered Hawk radar transmitter). One version included a cathode-ray tube (CRT) with motion picture and sound from video-disc. The second included a CRT with no video-disc, but with computer-controlled, 35 mm slide projection.
- c. We tested the alternatives by measuring how much skill carried over from training on the prototypes to actual equipment maintenance. ARI and its contractors (Science Applications, Inc., and Klein Associates) conducted the tests at Aberdeen (automotive training) and at Ft. Bliss (electronic training) for the following MOSs: 63B30, 63W10, 63H30, and 24C10.

¹ AMTESS: Army Maintenance Training and Evaluation Simulation System

d. We concluded that future simulators developed from the prototype-derived specifications could be cost-effective as part-trainers to support actual equipment training. However, as designed, they should not substitute

e. But there was far more to the AMTESS evaluation reports than the performance data that led to the above general conclusions. The reports contained a wealth of information about acquisition practices and design specifications which either did or potentially could limit the training effectiveness of the devices. Unfortunately this information was scattered and buried in hundreds of pages of mostly narrative text. We undertook this final effort in the AMTESS Program to pull together and organize in a usable way some specific ideas for what to include in device specs.

f. In this report we analyze the past reports and the "lessons learned" concerning the above acquisitions practices and design specifications. Our "lessons learned" flag the features of the acquisitions process that are most likely to procure inferior devices. The effort resulting Devices Acquisition Guidelines should be used by the specification writer to guide and check his specifications preparation. Thus the writer will avoid some of the most frequent mistakes in specifications preparation. These guidelines should not be taken lightly. The problems we have identified were produced by experts who were responding to a statement of work that already emphasized good specification preparation.

1.3 Background: Scientific

a. The broader scientific problem of how to translate human factors and instructional design data and principles into a form which training equipment designers can and will use is an old and persistent "chestnut" in applied psychology. Meister studied this problem 20 years ago. He provided a blueprint for a solution, which has been almost entirely ignored.

b. Meister et al. (1965a, 1965b, 1966a, 1966b, 1966c, 1967, 1968, 1969a, 1969b, 1971) examined the behavior of equipment designers at Bunker-Ramo, Douglas Aircraft, Marquardt, and Raytheon Corporations as they designed Air Force, aero-space, and Navy equipment under a variety of controlled experimental conditions. His purpose was to determine the normal use of human factors information, the normal quality of human factors design, and the conditions under which equipment design would be improved. He found that design engineers didn't normally use human factors principles, didn't have human factors references, and couldn't use human factors references when they were provided. They would apply good human factors and design excellent equipment only when the human engineering information was provided in the style that they were accustomed to, they were forced to use it by the SOW, and the human factors constraints in terms of numbers and types of personnel were specified in the SOW.

c. Meister concluded that the only way to obtain operable and maintainable equipment is to provide detailed functional specifications in the SOW. These must provide and highlight the human factors constraints on the system design.

d. William Askren, who sponsored some of Meister's research, continued it at Wright-Patterson AFB. He stated in a recent telephone conversation that Meister's research was applied, in part, by the Air Force, and that it was the genesis of the Navy HARDMAN effort which, in turn, led to the Army MIST and MANPRINT programs. The AMTESS "lessons learned" demonstrate that his principles for good equipment design are as valid now for training devices as they were for the actual equipment then.

e. Yet, these principles have not been applied with demonstrable success to the design and acquisition of Army training devices. PM-TRADE, through its support contractor, Science Applications International Corporation is beginning to apply the six categories of MANPRINT analyses to concept formulation. And, in the supporting OSBAT effort, ARI is developing algorithms to optimize the instructional design of training devices (Sticha et al, 1986). How well these approaches will translate into precise, comprehensive specifications and cost-effective training remains to be determined. But it should be emphasized that the Bradley specifications which we analyzed were developed at least partially under the new MANPRINT rules. One outcome of that analysis, incidentally, was to highlight this translation problem and suggest that it may remain inspite of the excellent efforts of MANPRINT and OSBATS. The PM-TRADE contractor agreed that "there is a requirement for a procedure to transition training requirements into specification languages" (Elam, 1987).

2.0 METHOD

2.1 Development of Device Acquisition Guidelines (DAG)

a. The objective of this exercise was to systematically collect the research-based guidance in the AMTESS reports that bears most directly on the production of engineering specifications for the manufacture of maintenance training devices.

b. To develop the contents of the Device Acquisition Guide (DAG) all relevant AMTESS reports were compiled and analyzed by training experts familiar with the device acquisition process and with the AMTESS Program. They were instructed to note and reference occurrences of the following:

- (1) AMTESS research results which suggest or indicate how future equipment might be designed more effectively.
- (2) References in the AMTESS reports to sources of published guidance on how to design training equipment.
- (3) AMTESS research which points to the need for additional research data on how to design training devices.

(4) Suggestions on how to improve acquisition procedures and avoid pitfalls in equipment acquisition.

c. Each of four experts independently read the AMTESS reports and extracted material judged to fit the objective. We then edited their respective products to eliminate duplications, and we consolidated the guidelines under eighteen subcategories of training device features and capabilities that could be specified in statements of work to procure devices.

2.2 Reverse Engineering of Bradley Trainer Specs

a. We applied the DAG to the specifications: for the Bradley Fighting Vehicle Maintenance Trainer (BFVMT). PM-TRADE selected these specifications as the target application of the DAG. Our aim was to determine whether and how well those specifications treated training effectiveness requirements which were short-falls in the AMTESS acquisition. For this exercise, training effectiveness included human factors, instructional design, and integration of the Bradley trainer into a program of instruction. This broad definition is critical since good instructional design is necessary but not sufficient.

b. Bradley Specs: We reverse engineered two specifications (Naval Training Systems Center 1986a, 1986b): The first specified four panel trainers with associated media (e.g. projection system, student station, instructor station). The second defined requirements for the Hands-on-trainer, Device 17-78.

2.3 Assumptions. The validity and usefulness of our results and conclusions depends on two assumptions:

a. Reasonableness of the AMTESS program as a test bed for cataloging Army device acquisition problems. The AMTESS program is more than reasonable, because an extraordinary amount of time and money were spent developing training effectiveness requirements, proportionately far more than is ever allocated to a training device program even under the MANPRINT mandate. Five companies, independently conducted concept formulations for the devices and the best two were selected to further develop and build the AMTESS prototypes.

b. Representativeness of the Bradley Specs. These specs were provided by PM-TRADE for this project. We have assumed that they are typical for Army training device acquisitions. Since this was an exploratory effort with very limited resources we could not analyze a large sample of device specifications to verify the assumption. A follow-up effort should do so.

2.4 Study Questions

- a. What lessons can we extract from the AMTESS Program?
- b. What do those lessons tell us about the quality of current training device specifications?

- c. How can we improve those specifications, using state-of-the art knowledge and technology?

3.0 RESULTS

3.1 Lessons Learned From AMTESS

a. Device Acquisition Guidelines (DAG). Appendix A presents the DAG which was derived from the analysis of AMTESS reports. We gleaned statements, conclusions, data, observations and do's and don'ts from those reports and then clustered them into the most meaningful categories we could think of. The DAG is, however, more an experience-based taxonomy of what can go wrong in an acquisition. It flags topics the specification writer should pay special attention to in addressing training effectiveness requirements.

- b. The DAG categories:

(1) Man-Machine Communication. This category includes all those design features which affect how well the operator and the device "talk" to and react to each other. Before the operator can learn anything he must receive information through his eyes, ears, muscle sensors, and skin, comprehend the meaning of the information, and then talk back to the machine. This may sound obvious. Yet, one of the AMTESS devices was judged to require reading abilities beyond those of the trainees.

(2) Hardware: A number of somewhat miscellaneous design characteristics do not fit neatly into the "communication" or instructional design categories, yet can affect the performance directly or indirectly of device users. These have been subdivided into hardware design, safety/hazards, and design for maintainability.

(3) Acquisition Management. With this category we shift away from design specifications per se to some do's and don'ts on how to manage the device acquisition. Again, as with the previous categories these recommendations are really AMTESS problems re-stated as guidelines.

(4) Human Factors and Software Design. Much can be done to misdesign computer software to impair the "human factor". Numerous examples were uncovered in the AMTESS evaluation and these have been sub-divided into problems affecting the trainee station and those affecting the instructor station.

(5) Instructional Delivery. This category recognizes that simulators are more than just 3-dimensional mock-ups. They are first and foremost teaching devices and as such need to include features which help instruct and assess student performance. And, their efficient use requires that they be properly integrated into the relevant POI along with other media such as 2-D part trainers. Accordingly, we have sub-divided this category into instructional features/principles, and student record keeping.

(6) Fidelity. This could well be a third sub-division under instructional delivery, but we've isolated it as a major category because device developers and builders have a special concern for it. Fidelity here refers to how much a simulation system resembles the appearance and behavior of the target weapon system. The issue of part vs whole training is included within this category.

3.2 What is the quality of current training device specifications?

a. How well do the Bradley specs address the problems cataloged in the DAG? We answered this question by "reverse engineering" the specifications for the Bradley Maintenance Hands on Trainer (HOT) and Panel Trainers. In the first of two procedures we enumerated the DAG categories and sub categories which were treated, not treated, or violated in the Bradley specs. The results of this enumeration are shown in Tables 1 - 3, Appendix B. Table 1 summarizes the item-treatment by specification. Tables 2 and 3 present a more detailed breakdown by DAG category. The data show that about 90% of the DAG items (i.e. AMTESS problems) were not addressed in the Bradley specs and therefore constitute potential problems in the Bradley trainers.

b. What is the quality of the content and structure of the Bradley specs? We read and analyzed the specs in detail with the help of the DAG. We arrived at five major findings.

(1) The word "training" is barely mentioned in either specification. Out of 164 numbered paragraphs in the panel specs, only 12 dealt with training issues. Out of 145 numbered paragraphs in the HOT specs, only 7 dealt with training issues. The remaining narrative paragraphs (Pages 1 -30 in the HOT specs, and 1-35 in the panel specs) in both documents dealt with engineering specs for mock-ups, as opposed to "trainers".

(2) The specs contain no indication about how the devices are to be integrated into a program of instruction, e.g. where and when are they to be used? ¹What training philosophy and strategy should they support? ²Failure to address this issue and its implied questions proved to be a major problem for the AMTESS program. Answers to these questions can and should influence the design of the training hardware and/or software.

¹ Elam wrote us that "the strategy of device use should then be part of the TDR which would assist us in determining (1) how many student devices will be required and (2) what training is to be accomplished by the device in relation to the task. Seldom accomplished".

² Elam stated that "TRADOC would be supporting this by the development of the course curriculum/syllabus which defines the strategy to be used with the device" (op.cit.).

(3) The specs, particularly those for the panel trainers, have serious and basic problems in logical organization. As a result, the few references to training effectiveness requirements are difficult to track. The general problem is that paragraphs are not organized into topic sentences and supporting explanations. Instead, related items of information are often spread across several paragraphs. For example on Page 7, Paragraph 3.2.1.2 of the BFV Panel Trainer Specifications, the author states "The trainee shall be required to perform all troubleshooting tasks in order and within a time standard". He explains this sentence four paragraphs later in Paragraph 3.2.3.

(4) Many terms and requirements are inadequately defined and therefore subject to being ignored or misinterpreted:

(a) For example, on Page 7 of the BFV Panel Trainer Specs, (Paragraph 3.2.1.1) the author states: "The training devices shall enable trainees to become proficient ..." What is the meaning of this requirement and what implication does that meaning have for the design of a trainer as opposed to the design of a simulator? And, how will the government know if this requirement has been met? It's well within the state of the art to specify a testing procedure and criterion for defining what is meant by "proficient."³

(b) A second example, is the statement on Page 7, Paragraph 3.2.1.1: "The BFVS Panel Trainers shall provide the capabilities for the instructor to demonstrate troubleshooting procedures ... to a variable class size in a classroom environment." Both "capabilities" and "class size" are undefined. Capabilities for example, should include panel displays which can be seen and understood five feet back and 60 degrees off the perpendicular which is where several of the trainees are going to be when this panel is demonstrated by the instructor. This may require displays which are artificially large. Here is a case where it might be necessary to distort fidelity of displays in order to use the device effectively for demonstrations.

(5) Citing Mil Standard 1472 Doesn't Work. Citation of 1472 in the AMTESS specs did not prevent extensive training effectiveness problems in the AMTESS devices, nor is it likely to do so in the Bradley trainer. A series of studies by David Meister beginning in 1967 indicated that equipment designers ignore human factors standards or don't know what to do with them. Meister suggested some alternatives to blanket citation of Mil standards. His suggestions were ignored. As a result, we have not made much progress in 20 years in helping engineers to design the human factor into training equipment.

³ Elam suggested including Measures of Training Effectiveness (MOTE) such as "% passing final test on device and % passing on first trial in actual equipment". (op. cit.)

3.3 What Can We Do to Improve Training Device Specifications Using State of the Art Knowledge?

We certainly don't know enough about how to design training equipment. But then we didn't know enough 20 years ago and probably won't know enough 20 years hence. Nonetheless we can do a better job of using what we do know or may know soon because of current research.

a. We can begin by solving some of the general problems cited above. Those problems are not beyond the state of the art, but they do call for more skills than the current specification writers have, e.g. instructional design, human factors, training effectiveness analysis, and technical writing, in addition to engineering. We don't expect the anesthesiologist to double as the brain surgeon. Yet, we ask the specification writer to do the job of five specialists. However, as an alternative to hiring five specialists for each device acquisition, we can develop decision and job aids. We need aids that will help the acquisition engineer organize his ideas and use whatever training effectiveness data and guidelines we can muster.

b. We can also use the lessons learned from AMTESS or any other acquisition experiences to identify specific device acquisition problems and then address those problems explicitly in the body of the specifications. This is what Meister recommended 20 years ago. Examples of how this might be done are presented in Table 1.0. The table presents the AMTESS deficiency associated with seven of the DAG subcategories as well as the result of the analysis of the BFVMT specifications. This portion of the table demonstrates that the DAG is relevant to recent training device procurements because the BFVMT specifications failed to specify device characteristics that proved troublesome in the AMTESS devices.

TABLE 1.0

Examples of How to Write More Precise Training-Related Specifications

DAG Category	AMTESS Deficiency	Bradley Deficiency	Suggested Specs
AUDIO INFO RATE	EXCESSIVE SPEECH RATE	NOT ADDRESSED	80 TO 120 WPM
DISPLAY DESIGN	READING LEVEL TOO HIGH	NOT ADDRESSED	USE FOG OR FORCAST E.G. 63MOS = 8TH GRA
CONTROL/DISPLAY INTEGRAT.	COMPUTER RESPONSE TIME EXCESS.	INCORRECT INCOMPLETE MISLEADING	CRT: .5SECS. PANEL: HI FI
SIMULATION FIDEELITY	TOO MUCH HI FI FOR TROUBLE SHOOTING	80 HARDWIRED EXCERCISES	HARDWIRE 20% OF REPEATED EXERCISES
SOFTWARE DESIGN	RESTARTS FROM BEGINNING	NOT ADDRESSED	RESTART AT STOP POINTS
STUDENT RECORD KEEPING	PRINTER OUT PUT: ILLEGIBLE UNREADABLE CODE	QUALITY, FORMAT CONTENT NOT SPEC'D	LETTER QUAL 10 POINT 8TH GRADE ENGLISH
STUDENT RECORD	INADEQUATE SUMMARY DATA	NOT ADDRESSED	SPECIFY SUMMARIES E.G. BY TASK BY CLASS

Commentary on Table 1. Several items in the table need some explanation.

1. "Use FOG or Forecast" Readability in the Army has taken on new importance with the recent publication of new DA regulations on clear writing (AR 600-70). And, it is certainly critical in design of training device displays. ARI's "Guidebook for the Development of Army Training Literature" explains what "readability" means and how to estimate it. The guidebook also lists examples of reading levels for a sample of MOSSs.
2. "CRT: .5 Secs., Panel: Hi Fi." What this cryptic message says is that a training device may have different computerized components and that different computer response times may be called for. In the Bradley, the student CRT display should respond to student actions in about .5 seconds, but the displays on the panels should mimick the response times of the actual equipment being simulated.
3. "Hardwire 20% of repeated exercises." The Bradley specs tell the device contractor to hard wire 80 trouble-shooting exercises. For many reasons, it would be more cost-effective to hard-wire just a few of these, e.g. 20 or 25%, and then present the rest on a 2-D device, e.g. interactive video disc. Such a mixture of media would allow the trainee to "feel" the actual hardware but do most of his training on the more flexible and available student station.

4.0 CONCLUSIONS

4.1 The collection of lessons learned from the AMTESS Program provide a useful and usable guide to likely deficiencies in training device acquisitions.

4.2 Training device specifications as represented by those for the Bradley Maintenance Trainer may be improved significantly by:

- a. Organizing topics and supporting explanations with clear, deliberate, and demonstrable logic.
- b. Defining training effectiveness terms and requirements explicitly and showing how they might affect the design of the training device.
- c. Explaining how the device is to be used in the program of instruction, e.g. indicating what training philosophy and strategy need to be supported by the device.
- d. Incorporating into the body of the specification those parts of military standards that are most relevant to the particular acquisition rather than relying on blanket citations or even abstract checklists of those standards.

4.3 It is possible to significantly improve the quality of training device specification with currently available knowledge.

4.4 Examples of what is wrong with current specifications and how to improve them were provided in the foregoing report.

4.5 Job and/or decision aids are needed to help the training device specification writer function competently, since he is now required to perform the functions of five different specialists.

Appendix A DEVICE ACQUISITION GUIDELINES

Using the Device Acquisition Guidelines.

A. What They Are

1. The Device Acquisition Guidelines (DAG) are lessons learned from problems faced in acquiring four prototype maintenance trainers in the Army Maintenance and Evaluation Simulation System (AMTESS) acquisition. More specifically the DAG consists of quotes and paraphrases taken from a number of reports investigating the problems of that acquisition as well as the device evaluation results. They can be used to alert personnel in the training device acquisition process to common acquisition problems.

2. The DAG is not meant to be exhaustive, but it does identify and help solve some of the more common and critical human factors and training design acquisition issues. The guidelines are based on good administrative, training and human factors procedures.

3. The answer to the question "Why?" for any guideline is that it was violated and the violation was related to a problem with at least one training device acquisition. Each guideline is the result of a specific problem in the acquisition of an AMTESS training device.

B. AMTESS References in the DAG:

Each guideline is followed by a citation in the form (n) p. nn.n. The number in parentheses is the number of the reference in appendix C from which the guideline was extracted. The nn.n specifies the page and paragraph containing the guideline so that the interested user can determine the exact conditions that produced the guideline. Sometimes the reference occurs in the middle of a guideline so that it can be next to the specific phrase with which it is associated. When this occurs, the reference is separated from the text with square brackets.

C. Information that was not derived from AMTESS

Sometimes we amplified the AMTESS guidance with administrative/training/human factors expertise that was not derived directly from the AMTESS studies. This information is enclosed in square brackets and is not followed with a reference. Guidelines I.B.1, I.B.3.b, and I.D.1 provide examples.

D. How to use the DAG

We believe that the best way to use the DAG is as a review device.

1. Prepare an outline of the desired document.

Check the DAG to find topics that should be added to the outline.

Reorganize the outline to bring related topics together.

2. Write the document.

Fill in the outline.

Use the DAG to provide the required specific information.

3. Review the product.

Compare each section of the product against the relevant sections of the DAG.

Include any missing information.

Perform normal review.

This procedure should enable you to avoid many of the usual pitfalls in training device acquisition.

E. DAG Categories

The DAG is arranged with seven main categories. The arrangement is shown below:

I. HUMAN FACTORS

- A. Audio Presentation.
- B. Controls/Display Integration.
- C. Ease of use.
- D. Visual displays and textual materials.
- E. Workspace Design.

II. HARDWARE

- A. Design.
- B. Safety and Hazards.
- C. Maintenance.

III. ACQUISITION MANAGEMENT

- A. Front End Analysis (FEA).
- B. Evaluation Requirements
- C. Training Device RFP/SOW:
- D. Design and device acceptance procedures:

IV. HUMAN FACTORS and SOFTWARE DESIGN

- A. Instructor Station.
- B. Student Station.

V. INSTRUCTIONAL DELIVERY

A. Instructional Features and Principles.

B. Student record keeping.

VI. FIDELITY

A. Basic considerations.

B. Two vs. Three Dimensional Considerations.

VII. NOTES

I. HUMAN FACTORS

A. Audio Presentation.

1. By analogy with video information presentation, audio presentations should be at an appropriate rate and volume of information so as to not overload the device user or compete unduly with other task training stimuli. (1) p. 50.1. Rule of thumb: 80 to 120 words per minute.

2. Identical audio signals, such as a "beep" tone should not be used to signal different task training conditions (e.g., the occurrence of an error vs a ready response). (1) p. 27.5, 51.3

3. Realistic simulation of sound effects should be provided when identified as important cues in the FEA. (3) p. 34.7

4. The presence of alerting or warning displays will improve user detection of conditions. (1) p. 24.3

5. A signal (audio or visual) will not have multiple meanings. (1) pp. 27.5, 51.3

B. Visual displays and textual materials.

1. Visual displays should incorporate an appropriate volume of information per frame or display so as to not overload the user with competing information. (1) pp. 49.7, 50.2 [Rule of thumb: 5 lines of text, 5 words per line.]

2. For visual displays, requiring the student to mentally trans- late displayed information should be avoided. Rather, displayed information should be presented as follows:

(a) Display only relevant info,

(b) Info is as precise as needed,

(c) Displayed info is immediately usable,

(d) The information remains displayed long enough to be detected. (1) p. 24.2-8

3. The language comprehension level (readability) employed in visual displays should be at a level appropriate to student reading comprehension generally an average high school reading level for military enlisted personnel. (1) p. 43.4

(a) Apply the fog index or other readability test to all textual materials. The maximum acceptable reading level is the minimum reading level for the MOS's being considered for training, as indicated by the school cutpoint. (1) p. 43.4

(b) [See ARI GUIDEBOOK FOR THE DEVELOPMENT OF ARMY TRAINING LITERATURE on how to measure readability and for examples of average reading abilities in Army personnel.]

4. The presence of alerting or warning displays will improve user detection of conditions. (1) p. 24.3

5. A signal (audio or visual) will not have multiple meanings. (1) p. 27.5

6. The system status mode or condition should always be clearly displayed for students and instructors. (1) p. 24.2

7. All labels will be legible, visible from the student location, permanent, and located per MIL SPEC 1472C, unless the device is a simulation which requires high physical fidelity. (1) p. 27.7, p. 51.4

8. Panel displays should not be ambiguous. (1) p. 51.4

9. Text materials presented on the student displays will be coordinated with the training being administered and with the technical manuals. (3) p. 33.2

C. Controls/Display Integration.

1. Control/Display relationship should be immediately apparent to device users. (1) p. 24.1

2. Device response features and student input controls should emulate the performance sensitivity of counterpart real world features (e.g., the training device features should not be unrealistically sensitive). (9) p. 83.2&45

3. Device computer programs and user input/output features should respond quickly enough and provide enough detailed and precise information to accomplish the system's purpose without stressing or discouraging the user or degrading user attention. (1) p. 24.10. The following are guidelines to achieve the above:

(a) [In normal operation the system will provide prompt acknowledgment of student input, 0.4 to 2.0 seconds.]

(b) [Non-psychomotor trainers will not provide feedback in less than 0.1 second.]

(c) [Psychomotor e.g. 3D trainers will replicate the response characteristics of the actual equipment. Provision may be made for variable system response to provide for slower or faster system response characteristics if these would improve training (i.e shaping the behavior is required).]

(d) [Multisense psychomotor simulation trainers (e.g. vision and motion) must have the cues to the different senses properly synchronized. This is more important than replicating the response characteristics for a single sense modality exactly. If the cues to the different senses cannot be synchronized, then the less important sensory modality should be disabled.]

4. Device response time, in the case of reinforcement and feedback, should reinforce or signal the student in a timely manner without undue delay. (9) p. 83.8&10

D. Workspace Design.

1. Device work spaces should be designed to incorporate easy and flexible to technical documentation. (6) p. 31.7

2. Students should be able to use the training materials easily and simultaneously with the simulation. (3) p. 43.3&4

E. Ease of use.

1. The operation of the new training device should not make additional demands on the students above those of the current training system. (5) p. 24.1, (10) p. 81.1

2. The utilization of the new training system should be cost-effective with reference to the instructor's time. (1) p. 43.2, (10) p. 80.2

3. Device computer programs and user input/output features should not limit or distort instructional objectives of the system. (1) p. 24.9

4. Instructor station should be as simplified as possible to assure ease-of-use, user friendliness, and minimal distraction from the instructor role. (1) p. 43.2, (3) p. 35.1

5. The instructor should not require much training to operate the trainer [i.e., relative to the training delivered by the training devices. (3) p. 35.1. Use job aids to help the instructor, where possible, e.g., where instructor will not be time stressed.]

6. Touch panel input on the CRT is preferred for student input. (1) p. 37.5

7. The student should be able to respond easily and naturally to the simulation and the training materials. The student should not require special training on idiosyncratic characteristics of the training device. (3) 43.3

8. For students with weak reading skills, the use of touch-screen or use of touch-panel can simplify learning where procedural skills are involved. (9) p. 86.1

9. The training device should allow the student to be trained on tasks that cannot be trained on the actual equipment. (3) p. 35.3

10. Schematics of every device should be provided to all [training sites] (6) p. 31.1, (10) p. 76.1

II. HARDWARE

A. Design.

1. System design, including cable length, will provide sufficient flexibility for ease of operation and observation. (1) p. 27.4

2. CRT will be adjustable to reduce glare, allow easy operation by students and instructor, and allow the operator and the display to be observed. (1) p. 27.4

3. Prototypes will be sufficiently rugged to survive the specified testing. (10) p. 77.1

4. Data back-up capability should be a device feature where important student performance data could be lost due to loss of device power (e.g., presence of constant voltage regulator or back-up battery power system). (1) p. 24.11

5. Device features which generate physical forces such as vibration or fields should be prevented from adversely affecting training controls/ stimuli and equipment intended to record student performance. (7) p. 18.2&4

6. Use video disks to provide relatively unchanging information. Store more information on the video disk than is required. (3) p. 42.6

7. Provide slide projector or large magnetic hard disks for storage of changeable information and to allow updating/correcting of training program. (3) pp. 33.4, 42.6

B. Safety and Hazards.

1. Device features should be free of physical dangers and irritants to individuals and clothing such as sharp corners/edges, unnecessary physical/audio/visual obstructions, or other hazards which interfere with student and instructor performance or detract from training conditions. (1) p. 27.9, 51.5

2. Cable connections will be sturdy and recessed. (1) p. 27.8

3. Cables will be sturdy and well protected, and equipped with ends that prevent excessive flexing motion. (1) p. 29.5

4. The simulator will be safer than the actual equipment (AE). (1) p. 36.3

C. Maintenance.

1. Device performance reliability should be high in order to maintain continuity and momentum of training sessions (i.e., drill, motivation, reinforcement). (7) p. 19.3

2. Training device features should be constructed with the goal of 95% operational availability [for system devices and 98% for non-developmental items] to minimize down time. (5) p. 42.4, (6) p. 32.1

3. Device hardware such as coils, bolts, switches, etc., should be "hardened" sufficiently to withstand the rigors of student use. (7) p. 20.6

4. Any remove/replace trainer should be able to withstand the attempts of novice students. (3) p. 34.3

5. MIL SPEC 1472C maintainability specifications will be required. Adequate access, illumination, labels, wire coding etc. will be used. Devices will be designed so that major components may be improved and replaced easily. (1) p. 29.4&5

6. A remove and replace repair philosophy will be used to the extent feasible. The device will be designed so that major components can be easily replaced. Special test components will be provided as well as replacement parts. Suspected components will be replaced with the test components and the system tested. When the faults are cleared the test components will

be removed, standard replacement components inserted, and the system retested. Defective components are repaired "off line". (1) p. 29.5 |implied by paragraph|

7. Equipment for operations training will be designed so that maintenance can be conducted from outside the device when this will allow easier access of the components. (1) p. 29.5 |implied by paragraph|

III. ACQUISITION MANAGEMENT

A. Front End Analysis (FEA).

1. Tasks to be trained will be selected by the initiating agency. (10) 67.1

2. Determine the requirements of the using organization and incorporate them into the SOW. Also determine if the requirements procedures may be undergoing review or change. (10) 78.2

3. Tasks/training requirements for which training devices are developed should be stable. They will be taught for several years in the same MOS. (10) 67.2.

4. The tasks/specific training requirements will be specified in the SOW. This suggests a separate procurement to perform the FEA. (10) 62.3, 71.1

5. Specify front end (FEA) procedures and documentation in the SOW. (1) p. 6.4

6. More than one subject matter expert will be employed in FEA activities requiring expert judgement. (10) 68.1

7. The fidelity analysis will examine the range of variables to be encountered in the training environment. (10) 73.1

8. Differences between SOP and expert opinion will be found and resolved. (10) 69.1

9. The results of the fidelity analysis will be incorporated in the device requirements. (10) 72.1

B. Evaluation Requirements

1. A detailed written evaluation plan is required. The plan shall be accepted by all involved government agencies. (10) 62.2 [This should detail a trainee performance test and minimal standards of learning to include tasks, action, condition, and standard/error rate .

2. The internal formative training evaluation plan will be developed as part of the FEA. (10) p. 8.13

3. The external summative validation plan will be developed as part of the FEA. (10) p. 8.13

C. Training Device RFP/SOW:

1. Terms used in RFP must be adequately defined. (10) p. 27.2

2. Precise device [functional] specifications shall be made available to the contractors. (3) p. 59.4, (10) 62.1

3. Specify training device evaluation procedures in the SOW. (1) p. 6.2

4. The SOW must specify training system products that can be validated (see rules on development of validation plan prior to SOW). (10) p. 27.3

5. The integration of the training device into the POI will be specified in the SOW. (10) 54.3&4

D. Design and device acceptance procedures:

1. Fully develop design acceptance procedures and criteria before contract award, preferably in the SOW. (1) p. 6.2

2. Fully develop device acceptance procedures and criteria before contract award. (1) p. 6.2

3. Criteria for device acceptance shall be comprehensive, precise, and fully understandable by all parties. (10) 62.1

4. Design acceptance procedures will specify how FEA incorporation into the device will be evaluated. (1) p. 6.4

5. Design and device acceptance procedures will incorporate training criteria and procedures for determining whether they have been satisfied, such as the Courseware Instructional Features Checklist. (1) p. 6.2

6. Apply relevant portion of MIL-STD-1472C as part of the design acceptance procedures. (1) pp. 21-29, 53.5

7. Apply MIL-STD-1472C based checklist as part of the device acceptance procedures. (1) pp. 21-29, 53.5

8. Prototype tests will include tests which require humans to exercise all features of the device. Problems will be noted and corrected. (1) p. 8.1

9. Transfer of training studies will be conducted on the prototype device. (1) pp. 8.1

10. Post-contract award changes to the training device will be reflected in changes to the design and device acceptance procedures. (1) p. 6.2

11. In addition, design and device acceptance procedures will include the following items:

(a) Device requires differential students' i.e., discrimination and generalization learning responses.

(b) Device provides unambiguous, concise feedback to response.

(c) Material is presented in order of difficulty or according to the logic of the discipline.

(d) Mastery of current material is required before student progresses to more difficult material.

(e) Previously mastered material is tested for retention later in the course [(1) p. 51.1]

(f) The assignment of functions to the trainee, the instructor, the device, and "other" must be presented formally for design acceptance and then checked during the device acceptance phase. (1) pp. 52.5-53.1 |implied|

12. Reliability and maintainability (RAM) analyses will be conducted. (10) 74.1

13. Full documentation, including schematics, will be provided with the equipment. (10) 76.1

14. Determine that the projected user can fully support the projected system. (10) 80.1

15. Student performance records will be produced and stored by all automated training devices. The records will provide the student's name and ID#. They will identify the training attempted and passed as well as time elapsed, error scores and correct steps per minute for each segment. (1) p. 43.5-44.3, 53.3.

16. Automated training materials will be easily updated and modified by the instructors. (1) p. 43.5-44.3, 53.3.

17. Instructors will be trained in all phases of the training devices. They will be trained and provided with materials required to train other instructors. (3) p. 60.5-6, 50.8

IV. HUMAN FACTORS and SOFTWARE DESIGN

A. Instructor Station.

1. The instructor station will be designed for an instructor, not a computer expert. (1) p. 37.9
2. Source code, compiler and linker programs will be provided in hard copy and in computer accessible form. (1) p. 37.7, (3) p. 35.2
3. The computer programming shall be done in a high level language. The language chosen will be one that can be mastered sufficiently by either the training developers or instructors that they can make the desired changes. [(1) p. 37.7, (3) p. 35.2] The changes include, but are not limited to:
 - reordering and skipping lessons [(6) p. 32.2];
 - updating and modifying materials [(1) p. 36.2&3, p. 43.2];
 - constructing new lessons [(1) p. 43.2].
4. Instructional authoring languages should be considered which will allow the training developer or instructor to change the instructional material easily and without extensive training. (3) p. 34.2

B. Student Station.

1. Device software, including authoring systems should provide in-depth on-line user guidance/assistance/help to the students, instructors and maintainers [(1) p. 29.1&6; (6) p. 32.4] including on-line assistance in system set up. (3) p. 33.3
2. Lessons may be restarted without stopping the system or losing existing data. They may be restarted where they stopped rather than at the beginning. Re-booting is viewed by students and instructors as a poor method for restarting a lesson or instructional module and should be avoided in device software design. (1) p. 36.2; (7) p. 18.12
3. Computer system messages will be clear, concise and uncoded. (1) p. 29.1&6
4. Computer-based systems will indicate their status continuously. The status indications will be ready for input, computing normally, error status. (1) p. 27.4, p. 29.1, p. 50.3
5. Computer-based systems will use error trapping routines to recover from unanticipated student and equipment errors. A default error trapping routine will indicate an error when the internal clock indicates the current task has exceeded a preset value. (1) p. 27.4

V. INSTRUCTIONAL DELIVERY

A. Instructional Features and Principles.

1. Determine mean and range of entering students' knowledge and skills. (10) p. 83.1

2. Viability of the device as an instructional delivery system should not be based only upon transfer-of-training hypotheses but also upon the considerations:

- (a) Cost,
- (b) Maintenance requirements,
- (c) Instructional flexibility,
- (d) Ease of use (6) p. 31.8

3. Instructional flexibility of a training device is an attribute that should be sought in device design and can be assessed by the following variables (there may be additional criteria as well):

- (a) Training can be altered at low cost and in little time; [(7) p.20.2]
- (b) Student progress can be self-paced; [(7) p. 20.2, (10) p. 44.5]
- (c) The order of training and segments can be readily changed; [(7) p.20.2]

4. Device features design should place emphasis upon providing opportunity for hands-on student practice with the training device. (6) p. 31.6

5. Device features design should reflect principles of good instructional practices. Courseware, for example, should not submit to hardware limitations when the net result is diminished instructional effectiveness. (1) p. 52.3

6. Device features which provide training stimuli should limit the number of stimuli presented at any one time to avoid requiring inordinate attention from students (i.e., should support focused instruction). (7) p. 20.5

7. To the extent possible device features should carry out training independent of the instructor so that the instructor is free to monitor student performance and provide student guidance/help. (1) p. 52.4

8. Training features of the device should accommodate various readiness levels of students so that the students can engage in a device -trained task at a level their skills accommodate. (10) p. 83.1

9. Learned behaviors should be applied immediately. (10) p. 44.3
10. Random malfunction selection is a good feature, but must not be the only way to select malfunctions. (3) p. 34.4
11. Maintenance trainers should provide a "troubleshoot only" mode. Part task trainers for "troubleshooting only" should be considered. (3) p. 34.6
12. The simulator will be designed to teach the hazards of the AE better than actual equipment. (1) pp. 36.1, 51.5
13. Students should not be allowed access to "help" until they have tried the task. (3) p. 43.5
14. Students who have requested "help" should be retested on that module later in the training. (10) p. 83.3
15. Material will be presented in order of difficulty [(1) p. 51.1, (10) p. 44.4] or according to the logic of the discipline (1) p. 51.1
16. The training device will require differential student responses. (1) p. 39.1
17. Performance feedback should be provided to the trainee. It should be unambiguous, concise and diagnostic, telling the student how to improve. (3) p. 34.5, (1) p. 51.1
18. Mastery of current material is required before student progresses to more difficult material. (1) p. 51.1
19. Previously mastered material is tested for retention later in the course. (1) p. 51.1

B. Student record keeping.

1. The instructor CRT can display both summary, and detailed information on the progress of each student and the class while the student is working. (1) p. 21.2
2. Student performance records will be produced and stored by all automated training devices. The records will provide the student's name and ID#. It will identify the training attempted and passed as well as time elapsed, error scores and correct steps per minute for each segment. (1) p. 43.5
3. Student performance records should be based on FEA task analysis. (3) p. 32.6

4. Student performance records will be self-explanatory to the student and the instructor. The output will be properly labeled and will not require a code book for interpretation. They will be available on line during the instructional sessions and will also be available in summary format across both training segments and students. (1) p. 43.5-44.1, 48.3, 50.3&4

5. The software that records student performance should provide the instructor with the ability to correct and annotate the record to identify equipment failures and other exceptional events, thereby preventing misinformation about student performance and the information required for repair. (1) p. 50.4, (3) p. 33.1

VI. FIDELITY

A. Basic considerations.

1. Determining the level of fidelity for device features should take into account, at least generally:

- (a) Task type,
- (b) Task difficulty,
- (c) Specific skills required to performed the task,
- (d) Trainee sophistication,
- (e) Stage of training,
- (f) Training context,
- (g) Device role in the overall POI,
- (h) User acceptance of the device ,
- (i) Supportive instructional features (10) p. 73.2

2. Simulation devices will not blindly replicate the actual equipment if improved training or maintenance can be provided. (1) 52.3

3. Emphasize development of part-task and lower fidelity maintenance simulators over major overall simulators. (10) p. 12.1

B. Two vs. Three Dimensional Considerations.

1. A moderate level of physical fidelity in a training device may be adequate for training a troubleshooting task (e.g., computer graphics or videodisc could be an adequate replacement for 3-D hardware). For remove and replace tasks, however, higher fidelity 3-D simulation is preferable. (6) p. 31.9

2. Most automotive and electronic maintenance tasks can be taught with 2-D media, and 3-D high fidelity is not required. (10) p. 53.2, (1) p. 37.3 Later studies have shown that 2-D is effective for teaching trouble-shooting to relatively advanced trainees, but that AE is better for remove/ replace level training.

3. 3-D modules are good to excellent for part training of vehicle maintenance procedures. (3) p. 32.3

4. 3-D training media must be thoroughly checked to determine if they are cost-effective. (10) p. 53.2

5. High fidelity device features are desirable for new and less experienced students. Advanced students often profit from reading and schematics. (3) p. 56.1

VII. NOTES

1. Reading level of text should match that of students. Students' reading grade level may be estimated from their AFQT scores. (As a design figure, the reading grade level should correspond to the AFQT entrance requirement associated with the MOS.) The reading grade level of text may be assessed by the FORCAST formula. (As a design specification, a tolerance of plus or minus one-half a level should be used. (1) p. 26.
2. The "mouse" is the preferred means of cursor moving for long data entry sessions because it avoids the arm fatigue experienced in pointing a light pen for long periods of time. (2) p. 344
3. The "highlight-response" system is the preferred means of selecting an item from a menu. (2) p. 346.
4. When using a light pen dialog, make certain that the "targets" for the light pen are at least 1/4" square. (3) p. 1.1-14.

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APPENDIX B. REVERSE ENGINEERING

The DAG is a compilation of lessons learned about training device acquisition during the course of the AMTESS program. The lessons were learned the hard way, i.e., when the devices were put to use, shortcomings became apparent. Because AMTESS was a research program, the shortcomings and their causes received considerable documentation. Are the resulting lessons learned applicable to current training device acquisitions? To answer this question the reverse engineering exercise analyzed two specification documents developed to acquire training devices for the Bradley Fighting Vehicle.

The analysis procedure was straightforward. Research psychologists familiar with the DAG searched specifications for "Bradley Fighting Vehicle Panel Trainers" and "BFVS HOT" to see if the items of the DAG were addressed. Three categories of data were enumerated: "treated", "not treated" and "violated". "Treated" meant that a phrase or paragraph in the specification addressed the concern of the DAG item. Thoroughness or rigor were not judged. "Not treated" meant there was no indication that the DAG item had been considered in the specification; "violated" meant that the specification expressed a requirement counter to that of the DAG item. Summary results are shown in Table 1.

Table 1.
Appearance of DAG Items in Specifications
for Two Bradley Training Devices

Training Device		
	BFV Panel Trainers	BFV HOT
No. of items treated	32	30
No. of items not treated	99	99
No. of items violated	7	9
Total no. of items	138	138

Tables 2 and 3 show breakdowns by DAG category for the two devices.

Table 2
 Appearance of DAG Items in Specification for
 Bradley Fighting Vehicle Hands-On Trainer
 by DAG Category

DAG Category	Number of Items		
	Treated	Not Treated	Violated
Human Factors (34 items)	5	27	2
Hardware (19)	10	9	0
Acquisition Management (39)	9	26	4
Human Factors and Software Design (12)	2	10	0
Instructional Delivery (26)	3	22	1
Fidelity (8)	1	5	2
	30	99	9

Table 3
 Appearance of DAG Items in Specification for
 Bradley Fighting Vehicle Panel Trainers
 by DAG Category

DAG Category	Number of Items		
	Treated	Not Treated	Violated
Human Factors (34 items)	8	26	0
Hardware (19)	10	9	0
Acquisition Management (39)	8	27	4
Human Factors and Software Design (12)	2	10	0
Instructional Delivery (26)	4	21	1
Fidelity (8)	0	6	2
	32	99	7

Examples of items:

The following are examples of DAG items and how they were classified.

Not Treated

"A signal (audio or visual) will not have multiple meanings."

"Touch panel input on the CRT is preferred for student input."

"Student performance records will be self-explanatory to the student and the instructor."

"Previously mastered material is tested for retention later in the course."

Violated

"The SOW must specify training system products that can be validated."

"To the extent possible device features should carry out training independent of the instructor so that the instructor is free to monitor student performance and provide student guidance and help."

"Prototype tests will include tests which require humans to exercise all features of the device."

Treated

"System design, including cable length, will provide sufficient flexibility for ease of operation and observation."

"Cable connections will be sturdy and recessed."

"MIL SPEC 1472C maintainability specifications will be required."

"Reliability and maintainability (RAM) analyses will be conducted."

APPENDIX C.
REFERENCES FOR DEVICE ACQUISITION GUIDELINES

Criswell, E. L., Swezey, R. W., Allen, J. A., & Hays, R. T. (1984). Human factors analysis of two prototype Army maintenance training and evaluation and evaluation simulation system (AMTESS) devices (ARI Technical Report 652). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A158 158)

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